3. Inner and Outer Coils

Four inner and **five outer** coils had been wound, cured and measured as potential coils for HGQ-05. All inner and four outer coils used in HGQ-05 are included in this report.

3.1 Winding and curing.

The nominal winding tension of 36.28 kG [80 lbs] was used for all turns on both inner and outer coils.
Two wedges, one per octant, were used in each outer and inner coil. 3mm gaps were placed longitudinally between end spacers and wedges on each end.
All inner and outer coils had the three piece wedge configuration on both sides (as noted on traveler).
All coils, both inner and outer, are cured in mold cavities, which are designed to have the precise cross section of the finished after they are assembled with the final design preload applied. Cavity sizes are, however, shimmed to adjust azimuthal coil size. Azimuthal coil sizes are changed to achieve the desired preload in the assembled magnet, based on prior empirical evidence. All inner coils had been recurred once to achieve this goal as well as reduce a difference in elastic coil modulus between inner and outer layers.
Curing mold cavity azimuthal shim was 178 - 711 mm [0.007-0.028 in] for inner coils and 127 mm [0.005 in] for outer coils with respect to design size. The coils are cured under radial and azimuthal pressure. The curing cycle was identical for both inner and outer coils. Temperature and pressure regimes are shown on Fig.3.1 and listed in the procedure below.

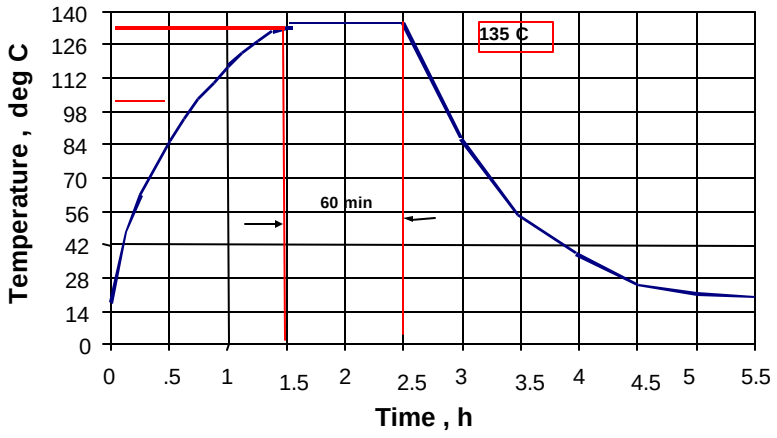

Figure 3.1. Coil curing thermal cycle.

Recuring cycle for HGQi-035 inner coil.

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1. Before installing end retainers, mark position of end saddle pushers at ends of mandrel with a permanent marker.
2. Complete packaging according to traveler and put mold into press.
3. Make sure end saddle pushers are inserted up to mark on pushers.
4. Close the last platen cylinder valve on each end. All mandrel cylinders are open.
5. Apply **2500** pump psi mandrel pressure.
6. Apply **1000** pump psi platen pressure.
7. Lower platen pressure to **500** pump psi.
8. Lower mandrel pressure to **500** pump psi.
9. Apply **750** pump psi end cylinder pressure.
10. Increase mandrel pressure to **3000** pump psi.
11. Increase platen pressure to **1000** pump psi.
12. Check gaps between mold stop and upper platen.
13. Starts heat cycle.
14. When T = **65** C check gaps.
15. Increase platen pressure to **4000** pump psi.
16. Verify that mandrel pressure is still **2500** pump psi
17. When T = **90** C check gaps
18. Increase platen pressure to **6000** pump psi.
19. Verify that mandrel pressure is still **2500** pump psi
20. When T = **105** C check gaps.
21. Lower platen pressure to **500** pump psi.
22. Lower mandrel pressure to **500** pump psi.
23. Lower end pressure to **250** pump psi.
24. Increase mandrel pressure to **2500** pump psi
25. Increase platen pressure to **4000** pump psi.
26. Increase end pressure to **750** pump psi.
27. Increase platen pressure to **8000** pump psi.
28. When T = **135** C check gaps.
29. After one hour at **135** C, turn off heaters. Maintain all pressures until coil is below **49** C.
30. After coil is below **49** C, release end pressure.
31. Release platen pressure.
32. Release mandrel pressure.
33. Remove mold from press.

3.2 Stabilizer.

The stabilizer (the same piece of cable ~30 mm long) was soldered on the cable at lead end of coils after curing to protect cable from popping strands and collapsing during the magnet assembly process.

3.3 Coil size and modulus.

Azimuthal size measurements of the coils are taken at a range of pressures encompassing those, which the magnet will experience during operation. Specifically, the coils are measured at pressure of 55MPa, 70MPa, 83 MPa and 97 MPa (8000 psi, 10000 psi, 12000 psi and 14000 psi).

Table 3.2. Inner Coil body size and Modulus.

Coil	Coil average modulus [GPa] at pressure range 55-97 MPa		Coil size at 83 MPa coil pressure [μm]			
	Average	Stand. Div.	Side A	Stand. Div.	Side B	Stand. Div.
I-035	7.9	0.25	221	15	223	12
I-036	8.4	0.37	201	13	220	19
I-037	8.0	0.42	210	28	191	22
I-038	7.8	0.28	212	15	231	22

Table 3.3. Outer Coil body size and Modulus.

Coil	Coil average modulus [GPa] at pressure range 55-97 MPa		Coil size at 83 MPa coil pressure [μm]			
	Average	Stand. Div.	Side A	Stand. Div.	Side B	Stand. Div.
O-028	11	0.36	329	20	306	25
O-029	10.6	0.3	309	18	270	24
O-032	10.5	0.34	339	19	331	18
O-033	11.	0.46	331	21	330	20

Coils are measured azimuthally in increments of 76.2 mm [3 in] along the straight section starting from the Lead End. Position #10 is in the middle of the coil straight section or coil body.

Size measurements and coil modules along inner and outer coils are shown in Figures 3.4 and 3.5.

A- side on which winding of, first turn begins, B- side which includes parting plane lead.

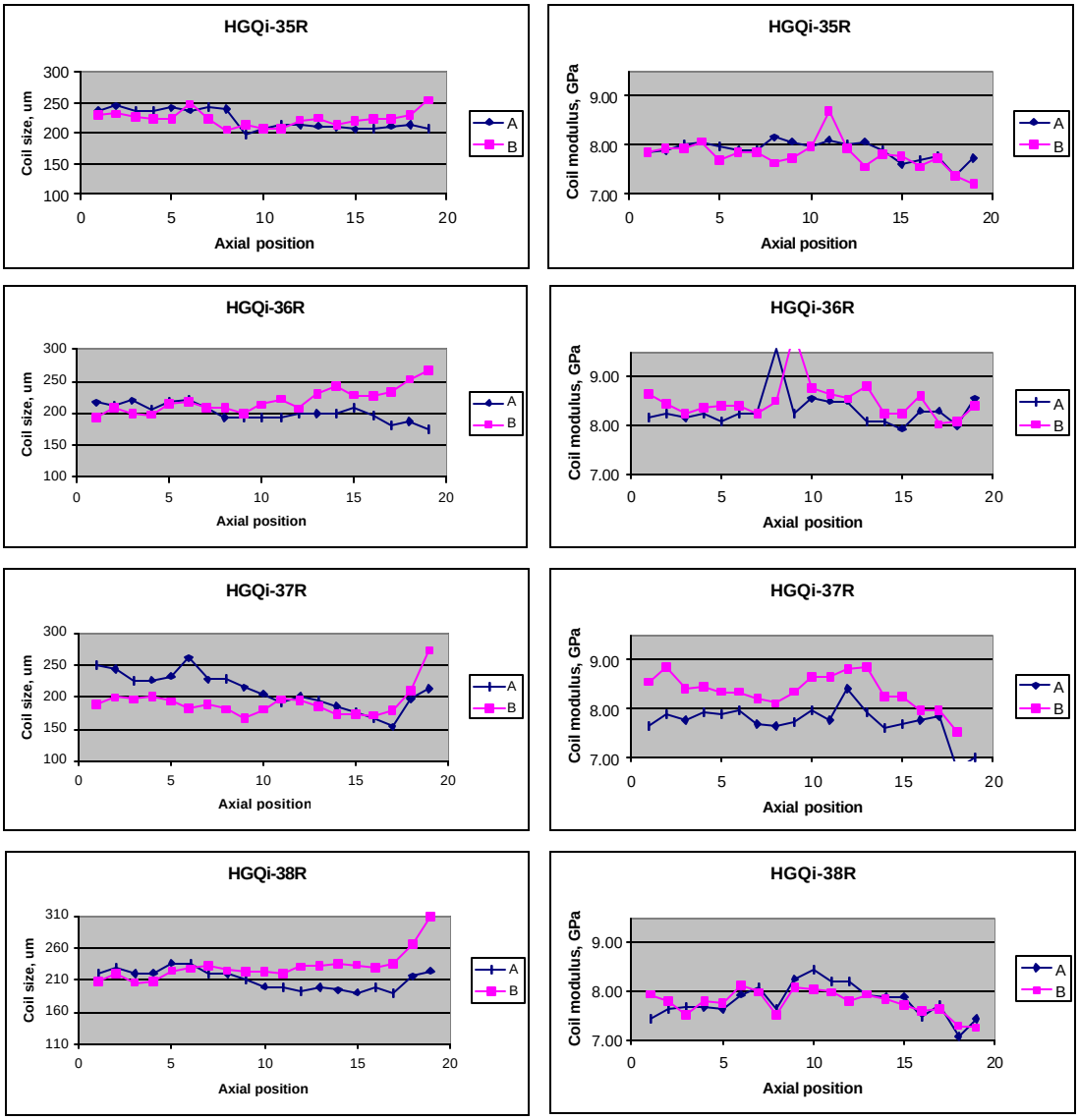

Figure 3.4. Inner coil azimuthal size and modulus along length.

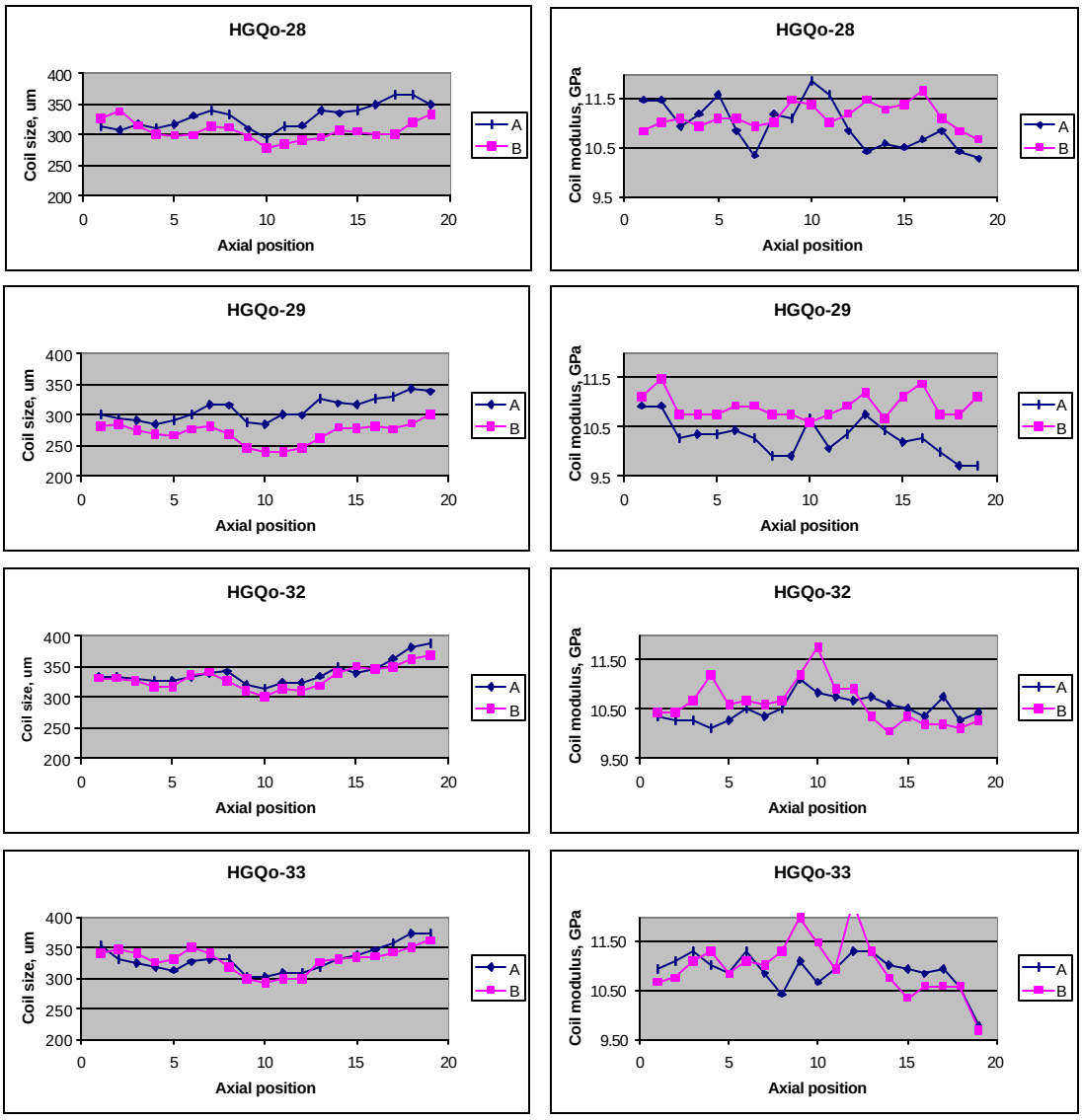

Figure 3.5. Outer coil azimuthal size and modulus along length.

The end fixture was designed to check electrically coil ends for turn-to-turn shorts at azimuthal pressures of 83 MPa (12000 psi). All coils passed this test successfully. This fixture was also used for coil azimuthal end measurements.

The measured area 25.4mm [1 in] was used for sizing along the coil's ends at pressure ~40 MPa. The results have shown on Fig. 3.6-3.9.

The radial and azimuthal pressure distribution on the ends as well as on the transition regions has been checked with 127 mm [5in] block at 83 MPa using a Fuji film.

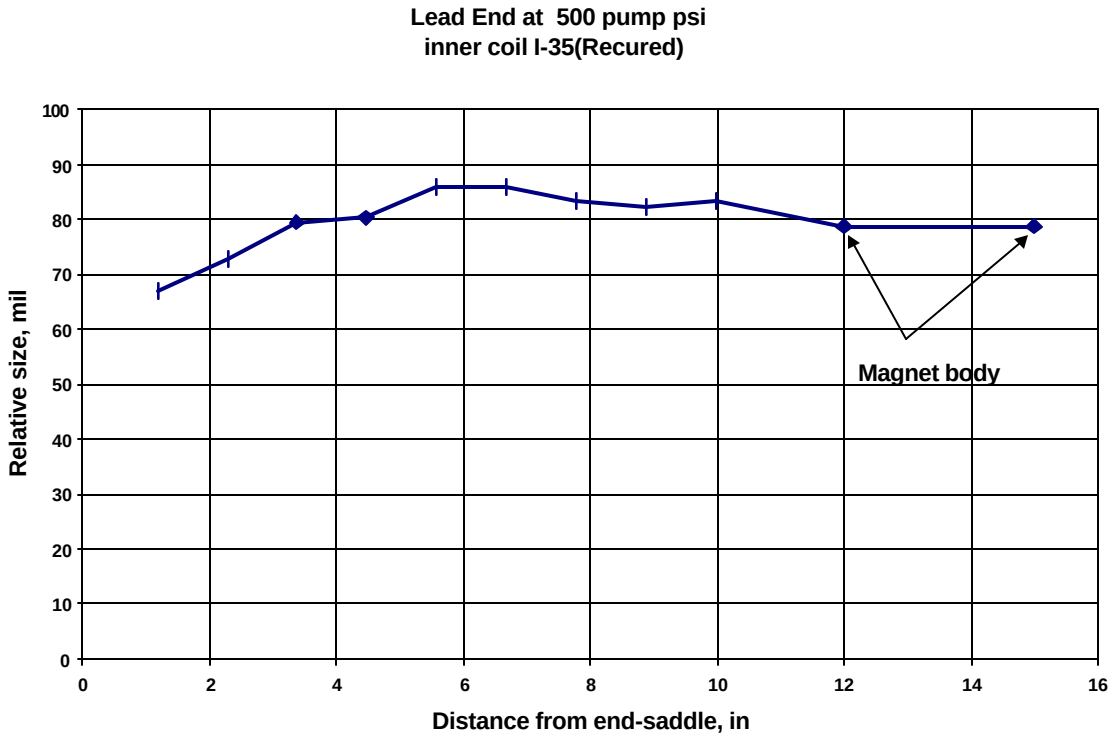

Figure 3.6. Lead End for coil I-35R.

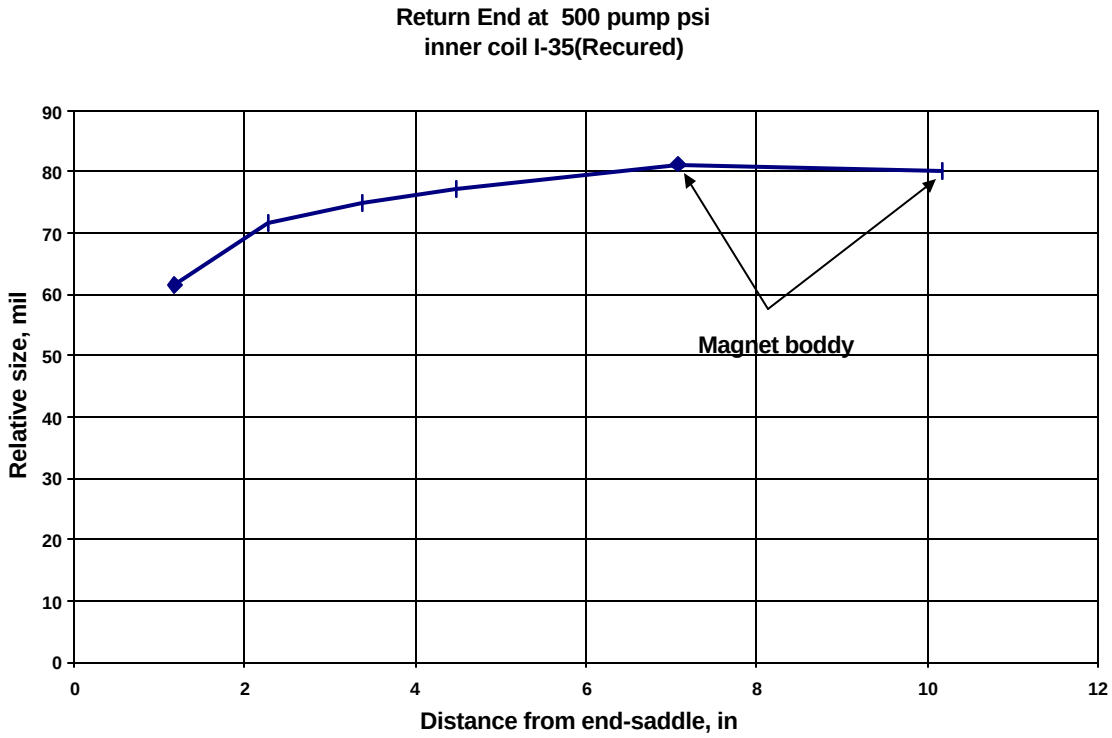

Figure 3.7. Return End for coil I-35R

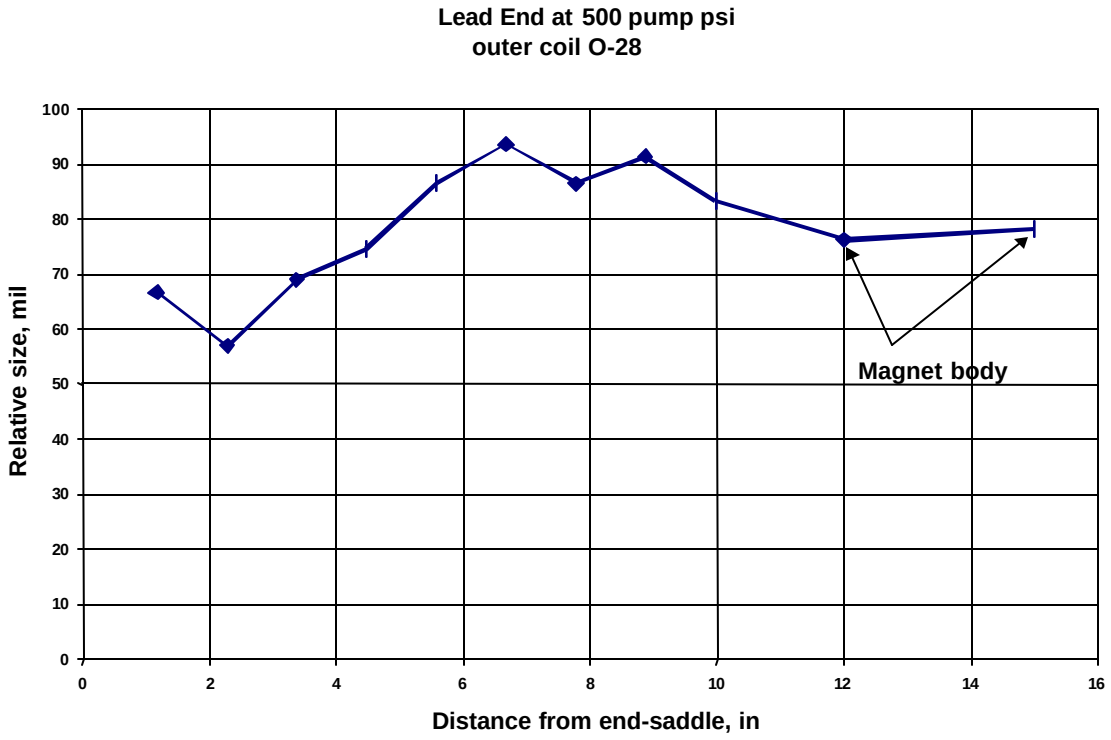

Figure 3.8. Lead End for coil O-28.

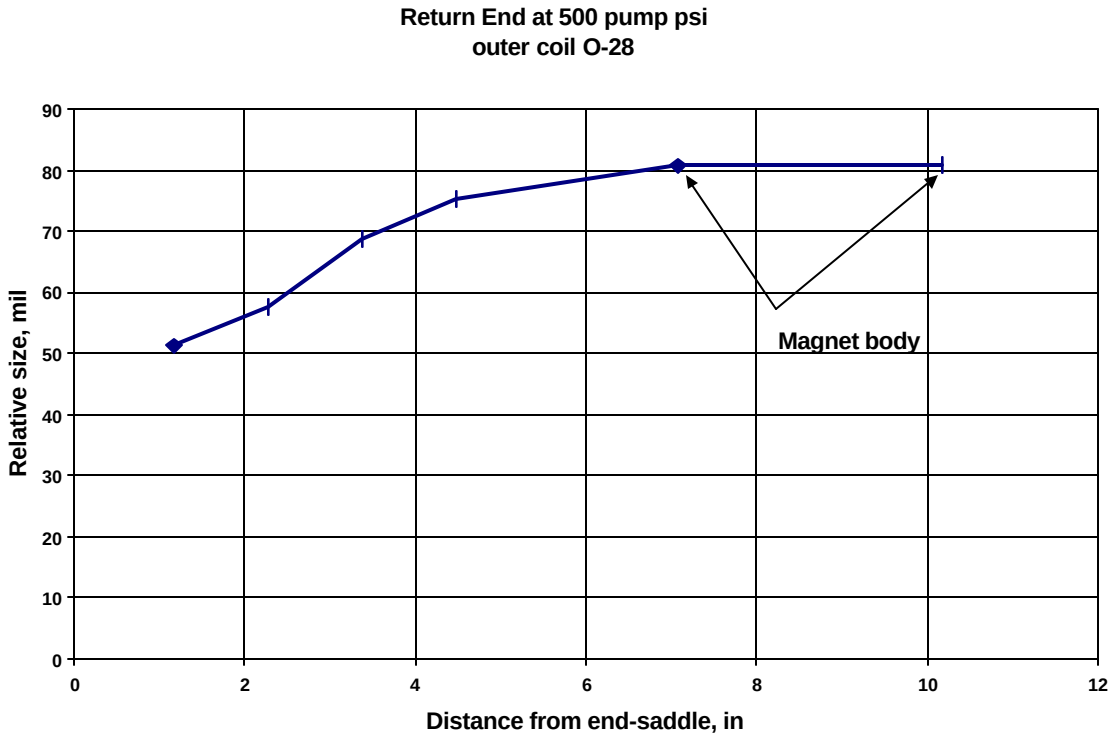

Figure 3.9. Return End for coil O-28.

3.6 Spot heaters and voltage taps.

The drawing numbers for voltage taps and heaters are 5520-MD-344972 and 5520-MD-344973.
All coils were tested in the end fixture after voltage tap installation. No shorts due to voltage taps were discovered during the end compression tests.